

# Delineation of Flood Prone Area using Normalized Difference Water Index (NDWI) and Transect Method: A Case Study of Kashmir Valley

Hilal Ahmad Ganaie<sup>1</sup>, Haseena Hashia<sup>2</sup> and Dheera Kalota<sup>3</sup>

Department of Geography, Jamia Millia Islamia, New Delhi-110025, India

<sup>1</sup>jmi.hilalahmad@gmail.com; <sup>2</sup>pro\_haseena@yahoo.co.in; areehd@gmail.com<sup>3</sup>

## Abstract

Floods of River Jhelum in Kashmir Valley are as old as the river itself. Historical accounts suggest that the river had witnessed the devastating floods since ages many among which have created havoc in terms their resultant destruction. The area which is mainly affected by floods are the Jhelum valley floor stretching from Anantnag in the south to Baramulla in the north. The Valley is an ancient lake basin 140 kilometre long and 32 kilometre wide. In this paper delineation of flood plain of Kashmir Valley has been carried out using Geographical Information System. The aim of this paper is to determine the accuracy of using simple digital image processing techniques to map riverine water bodies with Landsat 5 TM and Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data. This paper is divided into two parts, part-I deal with the Normalized Difference Water Index of Kashmir Valley and part-II deals with Transect method of river Jhelum. The 3D DEM and recent flood affected areas were used to supplement the above methodologies.

## Keywords

*River Jhelum; Flood Plain Delineation; NDWI; Transect Method*

## Introduction

Floodplains are hazardous to developmental activities if the vulnerability of those activities exceeds an acceptable level. Delineating flood affected areas and water bodies in general are always the most critical concern to deal with flood management operation. It is also an important input for planning and efficient management of flood affected areas. Accurate information on the extent of water bodies is important for flood prediction, monitoring and relief. Delineating non-flooded areas are also equally important because these areas can serve as a temporary shelter for the nearby affected areas. The management of the flood

prone areas depends upon the magnitude and frequency of floods. Flood is a relatively high flow of water that overtops the natural and artificial banks. Water spreads over flood plain and generally causes damage to inhabitants, crops and vegetation. During extreme flood event it is important to determine quickly the extent of flood water and different classes of land uses, which comes under water (Wang *et al.* 2002). Flood map can be applied to develop comprehensive relief effort immediately after flooding. Various Expert Groups like Working Group for Flood Control Programme for Xth Plan Rashtriya Barh Ayog (RBA) in 1980 in their reports have mentioned that there should be authentic flood prone area figures and suggested a scientific approach to be used in identifying the flood prone areas.

A floodplain is a strip of relatively smooth land bordering a stream and over flowed at a time of high water (Leopold *et al.* 1964). Floodplains can be looked at from different perspectives. As a topographic category it is a quite flat area and lies adjacent to a river. Geomorphologically, it is a landform composed primarily of unconsolidated depositional material derived from sediments being transported by the related stream. Hydrologically, it is best defined as a land with different return periods of the parent stream. A combination of these (characteristics) perhaps comprises the essential criteria for defining the floodplain (Schmudde 1968). However, an important process resulting in the formation of Valley flats is a combination of deposition on the inside of river curves and deposition from overbank flows. This process produced many of the flat areas adjoining river channels and probably most of the flood plains of the great rivers of the world.

As per Rashtriya Barh Ayog (RBA), the maximum area damaged/affected in any one of the years is assumed to be the area liable to floods in the state. The total of such maxima of the various states is considered to be the area liable to floods (Flood Prone Area) in the country. The RBA, however, recognized that annual flooding is not coextensive and that different areas are often flooded in different years by different streams. As per Centre Water Commission (CWC) records, based upon data of 1953-1978, the maximum area affected in any year in the country is 17.50 million hectares as against the area liable to floods which are 40 million hectares. The figure of 40 million hectares includes protected area of 10 million hectares, which was once flood affected area (Purba *et al.* 2006).

The information regarding the delineation of flood prone areas is difficult to collect using traditional survey techniques particularly during the floods. Remote Sensing technique is one of the efficient means of delineating water boundaries over a large area at a given point of time. The efficient methods for delineating flood extent using Landsat Thematic Mapper (TM) by distinguishing water and non-water areas are based on reflectance characteristics of a pair of images before and after a flood event using TM7+TM4 formula (Wang *et al.* 2002). For extracting moist areas Hudson used band 7 and 5 of Landsat Enhanced Thematic Mapper (ETM) image for separating permanent water, flooded and non-flooded areas after a flood event in Mexico (Hudson *et al.* 2003).

### Study Area

Kashmir valley one of the significant parts of Jammu And Kashmir State (India) is located between the Jammu and Ladakh. It is situated between 33°25' to 34°30' north latitude and 73°55' to 75°35' east longitude. Fig 1 shows the location of Kashmir Valley. The Valley is an ancient lake basin 140 kms. long and 32 kms. wide. The average elevation of the valley is 5,300 feet above sea level. The tall mountains that surround the valley from south and southwest by Pir Panjal range, in north by Kashmir Himalaya and in north and north east by Greater Himalayan range, which rising up to 16,000 feet ensure that the weather here is pleasant for most of the year and also gives birth to number of glacier-fed streams.

Climatologically, this area has semi-arid and cold climate that includes cold winter associated with snow and frost and moderate summer. In most cases the melting snow and rainfall are the main cause for

floods in Kashmir valley. One of the major rivers which run across the length of valley also known as its lifeline is the River Jhelum. The Jhelum is the main River of Kashmir valley with most of the towns and villages settled on its banks. The Jhelum and the host of streams constitute the drainage network of Kashmir valley. Every single drop of water, anywhere in the valley has to merge in the Jhelum that means any stream, rivulets and Nallas that flow in the valley ultimately merges into the Jhelum. The total length of the river is 212Kms. Its basin lies between the Greater Himalayas and Pirpanjal range.

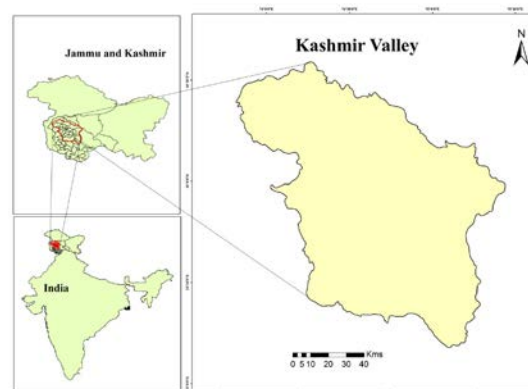


FIG. 1 LOCATION MAP OF KASHMIR VALLEY

### Flood Area Delineation

The delineation of flood prone areas in the Kashmir Valley has been carried out with various methods and techniques, like: Transect Method and NDWI. These methods have been done using Landsat TM and Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data. These methods are economical and efficient for delineating flood prone areas. The best methodology for the flood hazard delineation is using the pre-flood, during flood and post-flood satellite data. Remote Sensing data can be used to develop flood map in an efficient and effective way. From the early era of passive Remote Sensing, special attention has been given to distinguishing water from dry surface. Multi Spectral Scanner (MSS) band (0.8-1.1 Micrometer ' $\mu\text{m}$ ') has been found to be particularly suitable for distinguishing water or moist soil from dry surface due to its strong absorption of water in the Near Infrared (NIR) range of the spectrum (Smith 1997). Multi Spectral Scanner data has been used to deal with the flood-affected areas in Iowa (Rango and Solomonson 1974). For flood area delineation two sets of satellite data are required, one set consisting of data acquired before the flood event and the other acquired during the flood occurrence.

But there are certain limitations which do not allow us to go through this methodology for flood delineation as the satellite data is not readily available on various flood events. Keeping in view the data limitations the feasible techniques of flood prone areas delineation are NDWI and Transect Method.

## Methods

The delineation of flood prone areas in the Kashmir Valley has been generated by:

NDWI (Normalize Difference Water Index) and  
Transect Method.

*Normalize Difference Water Index:* The band Math function in ENVI 4.7 is used for computation of NDWI. The equation (2) is typed in the calculator and then the values b1 and b2 are identified in the LANDSAT MSS.  $NDWI = [(b1 - b2) / (b1 + b2)]$  (1)

b1 represents Green

b2 represents NIR (Near Infrared)

When equation (1) is used on Landsat MS satellite image that contains reflected visible Green band and NIR. Water features have positive values, while soil and terrestrial vegetation features have zero or negative values.

*Transect Method* (Topographic profile): Transect method or simply topographic profile has been used on five main discharge gauge stations, where peak water level data was available. Topographic profile has been done on Arc GIS 3D Analyst toolbar with the help of Interpolate Line tool, which clearly indicated the width of the flood plain on the SRTM DEM. The profile graph with distance along the profile route (in map units) is on the X axis, and elevation on the Y axis.

## Results and Discussion

### Normalized Difference Water Index (NDWI)

There are numerous vegetation indices developed to estimate vegetation cover with the Remote Sensing imageries. A vegetation index is a number that is generated by some combination of Remote Sensing bands. The most common spectral index used to evaluate vegetation cover is the Normalized Difference Vegetation Index (NDVI). McFeeters developed an index similar to the NDVI, which is called the NDWI. The Normalized Difference Water Index (NDWI) is being used to delineate open water features and enhance their presence in Remote Sensing

imageries. The NDWI is used to reach the goal of isolating water and non-water features in Kashmir Valley. The water bodies have a unique spectral response in the visible range when compared to the surrounding land cover. The infrared band classification gives a much better representation in the water related features than other visible bands. There are various definitions of NDWI that combine different pairs of bands (normally of TM or ETM), which include, Green and Near Infrared (NIR) (band2 and band4) (McFeeters 1996), NIR and Short Wave Infrared (SWIR) (band4 and band5) (Gao 1996) and Red band and Middle Infrared (MIR) (band3 and band5) (Xiao *et al.* 2002). There are several studies employing these pairs of bands to delineate flood prone areas. McFeeters NDWI is composed as:

$$NDWI = \frac{Band2 - Band4}{Band2 + Band4} \text{ OR } \frac{Green - NIR}{Green + NIR} \quad (2)$$

Where Green is a band that encompasses reflected green light and NIR represents reflected near-infrared radiation. The selection of these wavelengths was used because of following criteria:

- To maximise the typical reflectance of water features by using green light wavelengths.
- To minimise the low reflectance of NIR by water features.
- To take advantage of the high reflectance of NIR by terrestrial vegetation and soil features.

When equation (2) is used to process a multi-spectral satellite image that contains a reflected visible green band and NIR band, water features have positive values, while soil and terrestrial vegetation features have zero or negative values, owing to their typically higher reflectance of NIR than green light (McFeeters 1996).

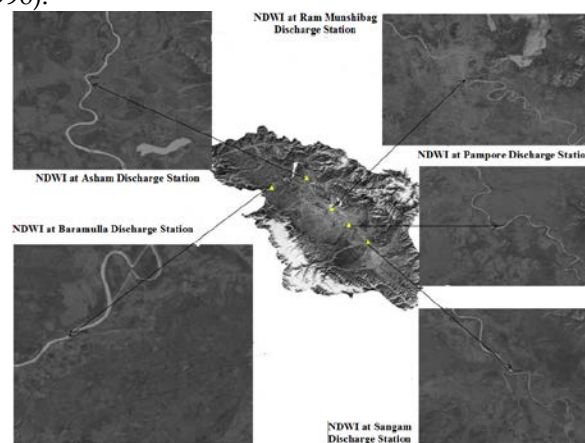


FIG. 2 THE NORMALIZED DIFFERENCE WATER INDEX AT FIVE DISCHARGE STATIONS OF RIVER JHELM IN KASHMIR VALLEY

Landsat TM image of the study area of October, 2010 was used to generate NDWI. The NDWI of Kashmir Valley is shown in Fig. 3, but due to the non visibility of water bodies and the course of river Jhelum, we generated NDWI at five discharge stations of river Jhelum. The Fig. 2 clearly shows the water and land masses of those five discharge stations. These stations are Sangam, Pampore, Ram Munshibagh, Asham, and Baramula. The availability of highest annual water levels from 1980 to 2008 is the main reason for the selection of above stations. If NDWI technique is used for the flood image, it would provide accurate results in the delineation of flood prone areas. In the absence of such data, an alternative method, Transect Method has also been used for delineation of flood prone areas in Kashmir Valley.

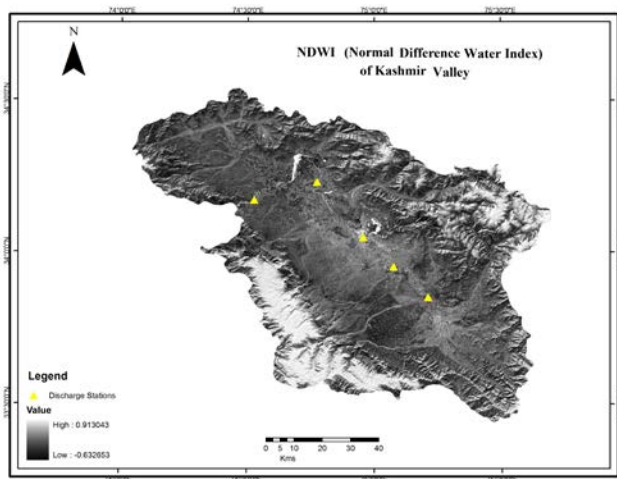


FIG. 3 THE NORMALIZED DIFFERENCE WATER INDEX OF KASHMIR VALLEY

#### *Transect Method to Delineate Flood Prone Areas*

A transect is a path which can count and record occurrences of the phenomena of the study. Transect measurements can be performed manually or through GIS application. In this method, the landscape positions (relative elevations) of riparian resources that are dependent on or sensitive to river water levels are surveyed along transects through the floodplain and river channel<sup>1</sup>. Observed water levels that inundate or saturate these landscape positions are correlated with water flows recorded.

The Flood Transect Method (FTM) is a field intensive method which establishes reference transects that span the river and onto the surrounding riparian zone. Through field visits and surveys at different stream flows, a relationship can be developed between flow,

water level and area of inundation. Alternatively, the relationship between stream flow, water level and habitat area can be developed through the acquisition of aerial photography at different stream flows. Where the FTM gives a vertical two-dimensional perspective, Remote Sensing Method (RSM) provides a horizontal two-dimensional perspective. The linking of both the ground based FTM and remotely sensed information through modelling RSM provides both the cross-sectional and channel length perspective for determining habitat area and its relationship with stream flow (Burack *et al.* 2009).

Generally, the active channel and floodplain are the main types of transect. The active channel transect is the sum of the widths of the actively flowing channels plus the bared bars. The floodplain transect is defined as the Holocene Valley, which can be identified using geological maps and DEM<sup>2</sup>. Often the computed water surface elevations are manually plotted on maps in order to delineate floodplains. Automatically this manual plotting would result in significant savings of both time and resources. A Geographic Information System (GIS) offers the ideal environment for these types of work through transect method. The Table 4.1 shows the highest water level above mean sea level at different stations.

TABLE 1 HIGHEST ANNUAL WATER LEVELS (METERS) FROM 1980-2008

Station	Sangam	Pampore	Ram Munshibagh	Asham	Baramula
Highest Water Levels (meters AMSL)	1,594	1,588	1,587	1,582	1,578
Year	1988	1995	1995	1995	1995

source: irrigation and flood control department srinagar. j&k

By using GIS based FTM for delineating flood prone areas, the topographical profile of Kashmir Valley was developed (Fig. 4.4). The topographical profile was generated on five main discharge stations which depict the cross profile of the Jhelum flood plain. The flood plain of river Jhelum is narrow at Sangam (Anantnag), therefore, the water level at this station is higher than the other discharge stations. The highest level of Jhelum was recorded 1,594 meters AMSL (in year 1988) at Sangam from 1980 to 2008. The topographical profile of Sangam shows the cross

<sup>2</sup>Holocene is defined as the time period encompassing the last 8,000 years to the present



section of the river extends upto 4.5 kms on Jhelum flood plain. The next site is at Pampore. The discharge data of this station shows that highest water level was 1,588 meters AMSL (1995). The below topographical profile of Pampore (Fig 4.4) shows that right side of river Jhelum has not been affected by the floods due to the Pampore *Karewa*. This shows that cross section of the river extends upto 6.5 kms on Jhelum flood plain. However, it extends when the embankment is breached and in this condition the water level reaches upto 10-15 kms and inundates those areas which were not affected by the floods.

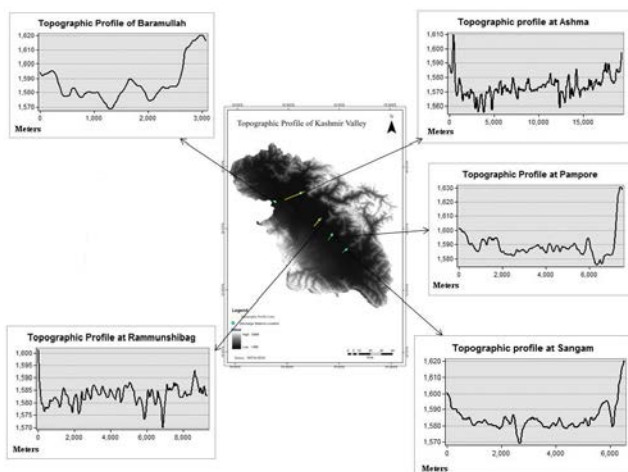


FIG. 4 THE TOPOGRAPHIC PROFILE OF KASHMIR VALLEY AT FIVE MAJOR DISCHARGE STATIONS OF RIVER JHELUM

The third station is at Ram Munshibagh (Srinagar) which is approximately situated at the middle of river Jhelum. This area was highly flood prone but after the construction of the Flood Spill Channel in 1903, regulated discharge is flowing safely through the Srinagar city. The topographic profile of Ram Munshibagh station (Fig 4) shows that the left bank of the river has large number of depressions which are flooded during the peak flow discharge. The maximum gauge height at this station during the past flood was 1,587.76 meters AMSL (1995), while the cross section profile shows that it covers the width of approximately 7 and 2 km on its left and right banks, respectively. Srinagar city is located on its right bank, where a large area is below the high water level but with the help of embankments and good drainage system the city was less affected. Asham (Bandipora) station is below the Shadi Pora (Bandipora) where the width of the Jhelum is about 35 kms (Raza *et al.* 1978). The Asham falls in the lower course of the river Jhelum and the highest water level was 1,581 meters AMSL (1995). The topographic profile shows that the extent of the river is about 19 kms. The last station is at Baramula, the highest water level at this station being

1,578 metres AMSL (1995) and the total width about 0.7 to 1.5 kms. After this station, river Jhelum leaves Kashmir Valley and enters Muzaffarabad [Pakistan Occupied Kashmir (POK)].

Finally three dimensional map (Fig. 5) has been generated with the help of Arc Scene to show the flood plain areas of the Kashmir Valley. The 3 D Image clearly indicates that the flood plain is mostly on left side of the river Jhelum. The usually flood affected areas has been demarcated by the Irrigation and Flood Control Department of Srinagar. Fig. 6 shows the flood affected areas of the Kashmir Valley.

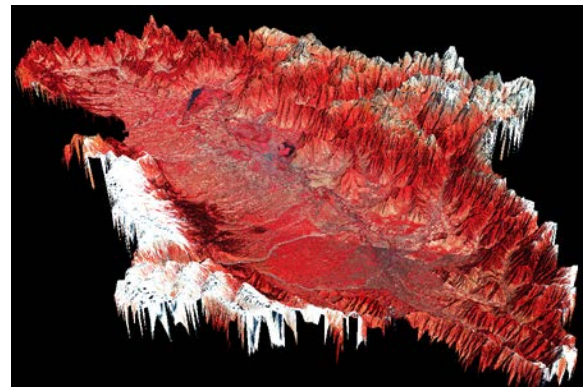


FIG. 5 THREE DIMENSIONAL MAP OF KASHMIR VALLEY

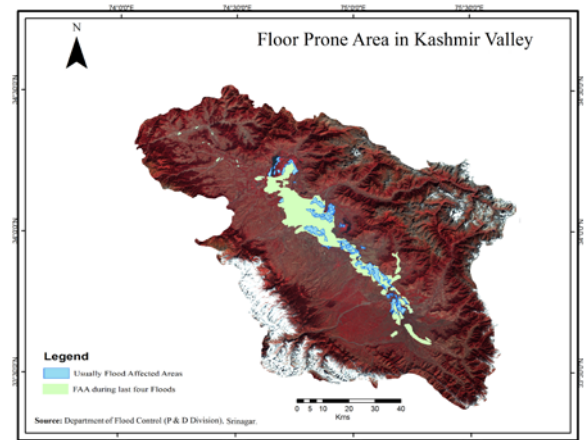


FIG. 6 FLOOD PRONE AREAS OF KASHMIR VALLEY

## Conclusions

Delineating flood prone areas play an important role in flood mitigating measures. The NDWI and transect method clearly shows that the lower Jhelum areas of Kashmir valley are more affected then the upper Jhelum areas. The transect method shows that the width of lower Jhelum areas is 20-30 kms and the upper Jhelum have 5-10 kms width. The flood management policy makers should mostly concern on lower Jhelum areas and funds should be allocated according to frequently flood affected areas for proper managemen.

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Name: Ganaie., H. A

Place: University of Jamaia Millia Islamia, New Delhi

DOB: 30/11/1981

Educational Background: Ph. D from University of Jamaia Millia Islamia, New Delhi, India in 2013.

Specilization: Diasater Management, Remote Sensing and Hydrology.

1. "The Composition, Processing, Recycling and Dumping of E-waste in the National Capital Region, India, *International Journal of Sustainability Development and Green Economics*, (2012), Environment and Sustainable development, Issues and challenges" 2. "Flood Disaster and its Management: An Exploratory Overview of River Jhelum in Kashmir Valley". Singh P. J., (eds) "Keshav Publications, Ghaziabad (New Delhi NCR) ( 2012), 3. *The Case structure in Kashmir Valley*. Jamia Geographical Studies (ed). Manak Publications Pvt. Ltd. New Delhi, 110092. (2012).



Name: Hashia, H,

Place: University of Jamaia Millia Islamia, New Delhi

DOB: 25/01/1959

Educational Background: Ph. D from University of Jamaia Millia Islamia, New Delhi, India in 1991.

Specilization: Gender Geography

She is working as Proffessor in Jamaia Millia Islamia University. She has number of publication and have presented number of papers in International conferences.



Name: Kalota., D.,

Place: University of Jamaia Millia Islamia, New Delhi

DOB: 30/11/1984

Educational Background: Ph. D from University of Jamaia Millia Islamia, New Delhi, India in 2013,

Research Scholar in Dept. of Geography,

Jamia Millia Islamia, New Delhi, India.

Specilization: Remote Sensing.